Introduction
The Groningen gas field is one of the largest onshore gas fields in the world. Induced seismic events due to gas production have been recorded in this field since the 1990s, the largest of which is the 2012 M3.6 Huizinge earthquake. In order to simulate rupture and sliding of induced seismic events or natural earthquakes, it is necessary to use a constitutive law for fault friction. However, existing friction laws are based on experiments at centimeter scale, while an earthquake rupture in nature occurs over hundreds of meters of fault area or more. This raises the question of whether the friction law derived from the small-scale experiments can be directly applied to such a large fault area, or whether larger scale heterogeneities affect the frictional strength and the constitutive parameters. To answer this, fault friction must be tested at least at the mesh scale of finite element models, i.e. at the scale of at least 0.5 to 2 meters. In 2018, we conducted a series of experiments using the large-scale friction apparatus driven by a shaking table at NIED, Tsukuba, Japan to explore the possibility of scale-dependent frictional properties of simulated fault gouges. We completed 34 experiments with 3 different gouge thicknesses (0.5 m, 1 m, 1.5 m), using simulated gouges prepared from Slochteren sandstone core materials.

Methods
We performed the world’s first meter scale friction experiments on simulated gouge filled fault, making use of the Large-Scale earthquake simulator (the shaking table) at NIED (the Japanese National Institute for Earth Science and Disaster Resilience). The shaking table in NIED allows direct shear experiment of large (up to 1.5m) blocks of rock at variable velocities.

Results
Mechanical Data

As shown in the table, a variety of data logging systems has been used to record the experiments continuously at high frequency. The images of the front surface were captured by an industrial camera at 500 or 1000 Hz and another two high resolution cameras at 0.5Hz.

Pressure sensitive sheet tests
From the pressure sensitive sheet tests give the normal stress distribution after the application of normal stress to the prepared gouge layer. The distribution of normal stress before experiment (the initial contact area) is distributed non-uniformly across the fault, concentrating on the edges. It means there is already some distribution of mechanical asperities when shearing starts.

Strain gage measurements

Strain gauge data from experiments with 3 mm gouge thickness at 3 MPa normal stress and variable length.

Strain tensor evolution by DIC

The T-S evolution of dilation before and after shear. Positive values correspond to dilation and negative values to compaction. The blue area in the small image on the left shows the locations of the virtual displacement sensors in the sample, and the gray bar indicates the location of the gouge layer. The strain field is continuously evolving. Before shear load is applied, there is already localization of deformation due to the variation in normal stress. These localization features are not necessarily along the fault, which means that under only normal load, the gouge is not participating much in the deformation. After shear load is applied, localization of deformation occurs along the gouge-filled fault.

Temporal and spatial (T-S) evolution of fault displacement

The T-S map of the rate of dilation (tensile velocity) before and after shear. There are waves of dilation propagating through the fault. Although the displacement modulation during shear is not qualitatively different from what happened beforehand, except that magnitude is much bigger.

Conclusions
1) For a fault filled with Slochteren sandstone gouge, the rate and state friction properties of large samples are not different from cm scale samples...
2) even though heterogeneity was observed in many aspects such as contact conditions, slip and strain distribution
3) Size does not seem to affect Rate-State friction behavior at length scales ranging from cm to 1-2m, for gouge thickness of a few mm.

Acknowledgements
This research is funded by the Nederlandse Aardolie Maatschappij (NAM). A.R. Niemeijer is funded by European Research Council starting grant SEISMIC (335915) and by the Netherlands Organization for Scientific Research (NWO) through Vidi grant 854.12.011. Thanks to Diede Hein for SEM images.